July 2004 • NREL/CP-550-36274

Conference Paper

BigHorn Home Improvement Center: Proof That A Retail Building Can Be A Low-Energy Building

Preprint

M. Deru, P. Torcellini, and R. Judkoff

To be presented at the World Renewable Energy Congress VIII and Expo
Denver, Colorado
August 29–September 3, 2004

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

Operated for the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
by Midwest Research Institute • Battelle

Contract No. DE-AC36-99-GO10337

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

BigHorn Home Improvement Center: Proof that a Retail Building Can be a Low Energy Building

Michael Deru, Paul Torcellini, and Ron Judkoff
National Renewable Energy Laboratory

Introduction

Most retail buildings are concerned with creating a comfortable, inviting environment for their customers. Energy efficiency and sustainable design are usually not part of the design process. The BigHorn Home Improvement Center is an exception to this practice; it is one of the nation's first commercial buildings to integrate extensive high-performance design into a retail space (Hayter and Torcellini, 2000). A multidisciplinary design team was established to investigate innovative technologies and design strategies that were available in the market to produce an energy-efficient building. The High-Performance Building Initiative (HPBi) at the National Renewable Energy Laboratory (NREL) was asked to participate in this process. In general, buildings in the HPBi demonstrate passive solar design and demand-side management strategies that can reduce building energy requirements by 50%-70% compared to buildings that meet the minimum requirements of standard energy codes.

Building and Site Description

The BigHorn Home Improvement Center is located in Silverthorne, Colorado, and houses an 18,400-ft^2 (1709 m^2) retail/office area and a 24,000-ft^2 (2230 m^2) warehouse/lumber yard. Silverthorne is a mountain community with an elevation of 8,720 ft (2,658 m), over 10,000 HDD base 65°F (5,555 base 18°C), and no CDD base 65°F. An illustration of the BigHorn Home Improvement Center with some of the energy efficiency features is shown in Figure 1. The retail/office space is on the right of the figure with a long east-west axis, and the warehouse/lumber yard is on the left side of the figure with a long north-south axis. The retail space and warehouse are single-story open interior floor plans. Most of the office space is on a second floor mezzanine. More information on this building is listed in the DOE High-Performance Building Database (DOE 2004).

The building envelope is well insulated to reduce the heating load, which is the primary energy load due to the cold winters and cool summers. The heating in the retail/office area and employee break room is provided by a hydronically heated radiant floor system with nine heating zones. This system is simple, efficient, and provides a comfortable environment. The warehouse is designed to be a drive-through loading area for lumber and building materials; therefore, at least one of the overhead doors is open during business hours. Radiant gas heaters are used to maintain the space temperatures above 37°F (2.8°C). A transpired solar collector on the south wall provides warm ventilation air when there is sufficient solar heat gain on the wall.

In the summer, the retail area and offices are kept cool by avoiding solar heat gain, using daylighting instead of electric lighting, and by the use of natural ventilation. Natural ventilation is provided through north-facing clerestory windows that are operated by an Energy Management System (EMS) and manually opened doors on the ground level.

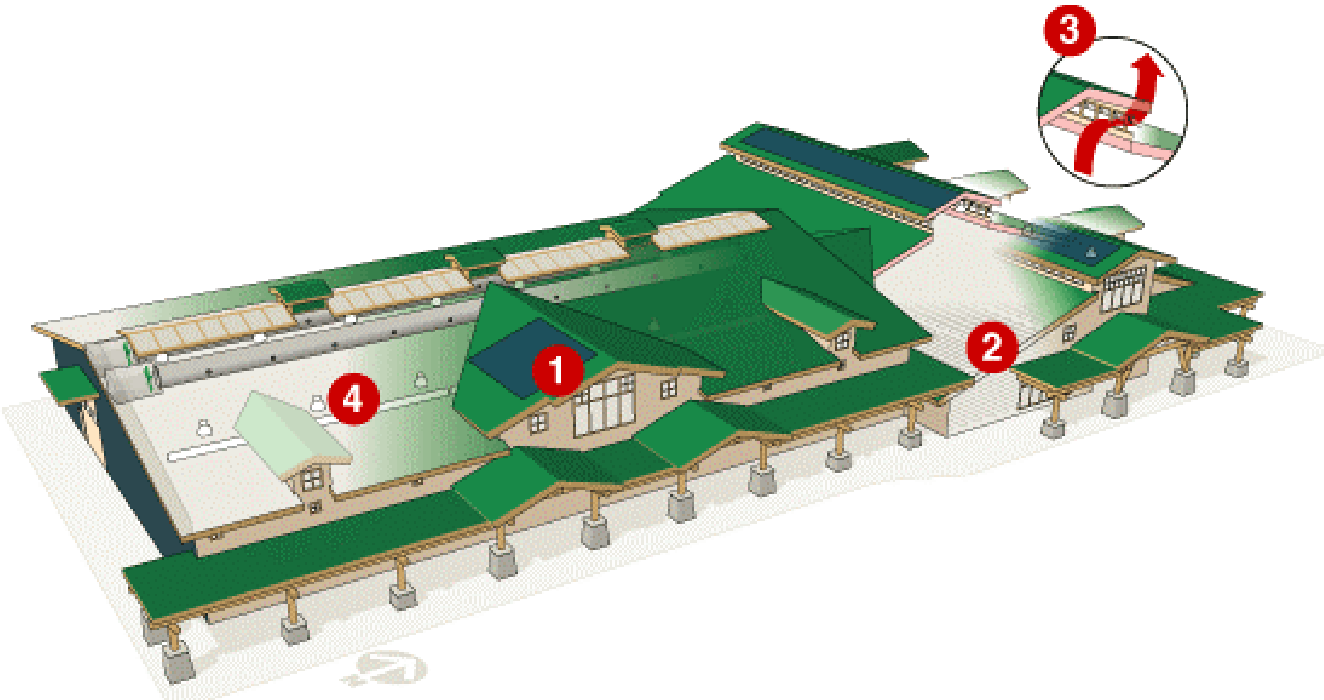

Figure 1 Illustration of the layout and some of the energy features of the BigHorn Home Improvement Center (1) Photovoltaic panels, (2) radiant floor heating, (3) natural ventilation, and (4) daylighting.

Daylighting is provided in the warehouse primarily through insulated translucent skylights along the ridgeline and dormer windows on the east wall. Daylighting strategies in the retail area include the following: north- and south-facing clerestory windows run the length of the store; three dormer windows on the north side; high windows on the east and west ends of the building; and a borrow window from the warehouse. The daylighting controls are provided by the EMS using three light sensors (exterior, retail, and warehouse). The luminaires in the retail/office area and the warehouse are high-output, high-bay fixtures that use eight 26-W CFLs. The lamps can be controlled two at a time, providing five lighting level steps for each fixture as an energy-efficient way of matching the available daylighting.

Other energy-efficient features of the building are the grid-tied roof-integrated photovoltaic (PV) system. The 8.9-kW PV system consists of amorphous silicon panels that are laminated onto the conventional standing-seam metal roof. A transpired solar collector is installed on the south wall of the warehouse. This system includes a 2,250-ft^2 (209.0 m^2) perforated, dark metal absorber panel with an air space behind it and provides heated ventilation air to the space. The EMS is used to control the operation of the HVAC, snowmelt, clerestory windows, and lighting systems in the building.

Energy Performance Evaluation

The energy performance of the BigHorn Center was evaluated extensively for three years by continuous end use monitoring, analysis of utility bills, walk through inspections, spot measurements, and computer simulations. A dedicated data acquisition system (DAS) was designed to monitor and archive the performance data.

Energy simulations of the as-built building were completed to better understand the energy performance and compare it to an energy code compliant baseline building model. The baseline building model was developed to reflect the size and functionality of the as-built building and meet the minimum thermal efficiency requirements of ASHRAE Standard 90.1-2001 (ASHRAE 2001). The baseline building model was created following the guidelines of the proposed Addendum-e to ASHRAE 90.1-2001. Both building models were calibrated with the building operations and measured energy and weather data. All of the simulations were conducted with DOE-2.1E (DOE2.1E 2004).

After the calibration process, the two simulation models were run with a weather file based on the long-term average weather conditions to show the performance and savings for an average weather year. The annual site energy consumption by end use for the two building models is shown in Figure 2 and Table 1. The net site energy saving was 36% and the net source energy saving was 54%, which includes the measured energy production from the PV system. The energy cost saving was 53%. In addition, the simulations predicted that the average monthly peak electrical demand would be reduced by 59% from 124 kW for the Baseline Building to 50 kW for the As-Built Building. The reduction in the annual peak demand is mainly due to the elimination of the HVAC fans and the reduction in the lighting power.

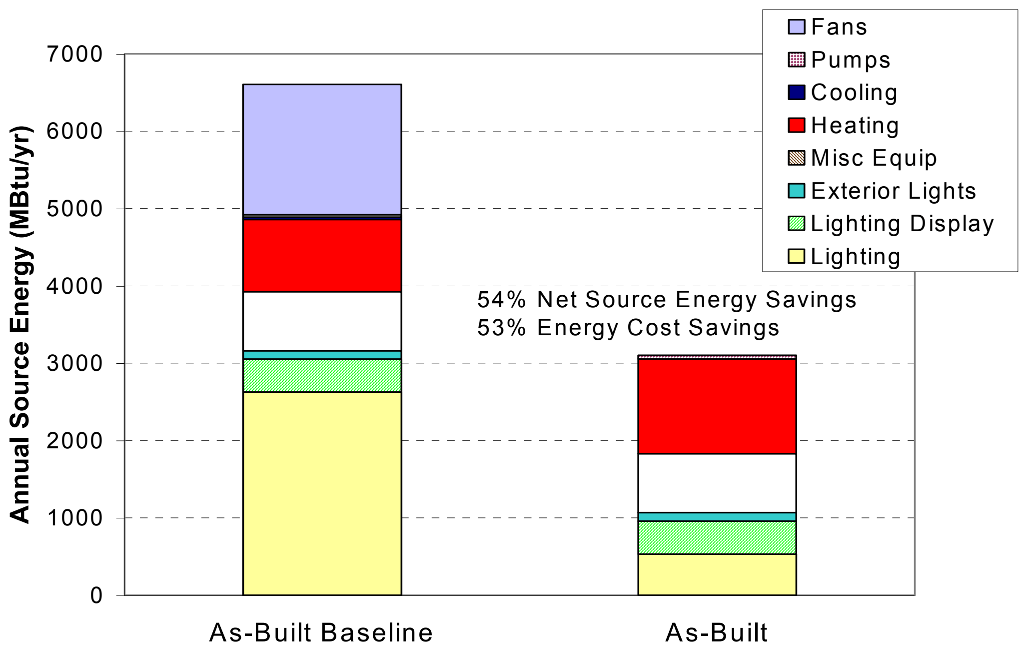

Figure 2 Annual source energy consumption for the Baseline Building and As-Built Building models using an average year weather file.

The energy use patterns for the retail/office and warehouse spaces are very different, and the simulation models allow us to look at the spaces separately. The retail/office space shows an annual site energy saving of 24% and a source energy saving of 44%. These energy savings result from a reduction in the lights and from the elimination of the fans and cooling load. The source energy saving in the retail/office space is much larger than the site energy saving due to the more efficient use of gas than electric lights and fans to heat the building. The warehouse has a 50% site energy saving and a 79% source energy saving. The site and source energy savings come mainly from the reduction in the lighting loads and the elimination of the fans.

Table 1 Annual Facility Energy Use from the As-Built Simulations (end use numbers are for site energy use)

Performance Metric	Units	Baseline	As-Built	% Saving
Lighting	(MBtu/yr)	830	168	80%
	(GJ/yr)	875	178	
Lighting Display	(MBtu/yr)	135	135	0%
	(GJ/yr)	142	142	
Exterior Lights	(MBtu/yr)	35	35	0%
	(GJ/yr)	37	37	
Misc Equip	(MBtu/yr)	241	241	0%
	(GJ/yr)	254	254	
Heating	(MBtu/yr)	861	1130	-31%
	(GJ/yr)	909	1192	
Cooling	(MBtu/yr)	9	0	100%
	(GJ/yr)	9	0	
Pumps	(MBtu/yr)	11	15	-41%
	(GJ/yr)	11	16	
Fans	(MBtu/yr)	532	0	100%
	(GJ/yr)	561	0	
Average Monthly Peak Demand	(kW)	124	50	59%
Total Site EUI	**(kBtu/ft^2·yr)**	**62.6**	**40.7**	**35%**
	(MJ/m^2·yr)	**711.1**	**461.9**	
Net Site EUI	**(kBtu/ft^2·yr)**	**62.6**	**40.3**	**36%**
	(MJ/m^2·yr)	**711.1**	**460.8**	
Total Source EUI	**(kBtu/ft^2·yr)**	**155.9**	**73.3**	**53%**
	(MJ/m^2·yr)	**1771.0**	**832.1**	
Net Source EUI	**(kBtu/ft^2·yr)**	**155.9**	**72.1**	**54%**
	(MJ/m^2·yr)	**1771.0**	**819.4**	
Total Energy Cost Intensity	**(kBtu/ft^2·yr)**	**$1.08**	**$0.51**	**53%**
	(MJ/m^2·yr)	**$0.100**	**$0.047**	

The lighting systems in the BigHorn Center are extremely effective at reducing energy consumption. The overall energy saving is 80% and the energy saving in the retail/office area is 67% and 93% in the warehouse compared to the energy use by using the lighting levels allowed by energy code.

One of the largest energy cost savings in the BigHorn Center is the reduction of the electrical demand. The average monthly peak electrical demand was reduced by 59% over the baseline building. However, the electrical energy consumption in the building has been reduced so far that the demand charges are over 60% of the electric utility charges. An analysis of the detailed data reveals that the peak demand for most months is caused by charging the electric forklift or turning on most of the lights during cleaning.

Both of these events could be easily controlled to reduce the peak demand. It is estimated that charging the forklift at night would have saved an average of $800 a year.

In 2003, the PV system provided 2.5% of the annual electrical energy. It is estimated that the PV system saved only $108 in energy cost. The low energy cost saving is mainly due to the PV system output that does not coincide with the monthly building peak demand. The utility rate structure has a high demand cost and low energy rate cost. Operating problems with the PV system reduced the annual performance by approximately two thirds of expected amount. The problems are mainly due to the use of old inverter technology that does not have power-point tracking ability and is not meant to be connected to the electrical grid. At the time of installation of this system, grid-tied inverters were not available and a special circuit was designed to use stand-alone type inverters (Hayter et al. 2002).

Conclusions

The owners of the BigHorn Home Improvement Center worked with NREL to improve the design of their facility by using NREL's computer-simulated, whole-building approach that looks at the way the building's site, envelope, electrical, and mechanical systems work together most efficiently.

Overall, the BigHorn Center uses 54% less source energy and has 53% lower energy costs than typical retail buildings of similar size. The extensive use of daylighting has reduced the lighting energy requirements by 80%, which contributes significantly to the reduced energy loads in the building. Reduction in the lighting and control of solar gains has lowered the internal gains enough to be able meet all the cooling load with natural ventilation. The 8.9-kW photovoltaic system provides 2.5% of the electricity needed to operate the building. Improvements to the PV system and building operation should improve the performance to near 8%.

References

ASHRAE 2001. *Energy Standard for Buildings Except Low-Rise Residential Buildings.* ANSI/ASHRAE/IESNA Standard 90.1-2001. Atlanta, GA: American Society of Heating, Refrigerating, and Air Conditioning Engineers.

DOE 2004. High-Performance Buildings Database, BigHorn Home Improvement Center. http://www.eere.energy.gov/buildings/highperformance/case_studies/overview.cfm?ProjectID=54. (Accessed April 2004).

DOE-2.1E 2004. DOE-2 Energy Simulation Software, http://gundog.lbl.gov/ (Accessed April 2004).

Hayter, S. and P. Torcellini. 2000. "A Case Study of the Energy Design Process Used for a Retail Application." NREL/CP-550-28129. Presented at the American Solar Energy Society Conference. June.

Hayter, S., P. Torcellini, and M. Deru. 2002. "Photovoltaics for Buildings: New Applications and Lessons Learned" NREL/CP-550-32158. Presented at the American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Buildings. Pacific Grove, CA, August 18-23.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
July 2004

2. REPORT TYPE
Conference Paper

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
BigHorn Home Improvement Center: Proof that a Retail Building Can Be a Low Energy Building; Preprint

5a. CONTRACT NUMBER
DE-AC36-99-GO10337

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
M. Deru, P. Torcellini, and R. Judkoff

5d. PROJECT NUMBER
NREL/CP-550-36274

5e. TASK NUMBER
BEC3.1001

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/CP-550-36274

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*

The BigHorn Home Improvement Center in Silverthorne, Colorado was one of the first commercial buildings in the United States to integrate extensive high-performance design into a retail space. After monitoring and evaluation by NREL, the BigHorn Center was found to consume 54% less source energy and have 53% lower energy costs than typical retail buildings of similar size. The extensive use of daylighting to replace electric lighting reduced lighting energy requirements by 80% and significantly contributed to the reduced energy loads in the building.

15. SUBJECT TERMS
BigHorn; High-Performance Buildings; daylighting; World Renewable Energy Congress; commercial buildings; high-performance design

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	UL		19b. TELEPONE NUMBER (*Include area code*)